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CLAIMS

We Claim:

1. A method of electroplating a metal onto a surface comprising a field region and a recessed feature, the method comprising :

a) contacting said surface with an electroplating solution comprising metal ions and an additive; and

b) applying a cathodic current through said surface, the cathodic current being sufficiently small that depletion of metal ions and the additive is absent at both the field region and the recessed feature, resulting in substantially conformal electroplating of said surface.

2. A method of electroplating as in Claim 1 wherein said cathodic current is a dc current in the range from approximately 0.1 milliamperes per square centimeter to approximately 5 milliamperes per square centimeter.

3. A method of electroplating as in Claim 2 further comprising cathodic current pulses superimposed on said dc cathodic current.

4. A method of electroplating as in Claim 3 wherein said cathodic current pulses carry currents in the range from approximately 25 milliamperes per square centimeter to approximately 250 milliamperes per square centimeter.

5. A method of electroplating as in Claim 3 wherein said cathodic current pulses have pulse lengths in the range from approximately 0.5 milliseconds to approximately 10 milliseconds.

6. A method of electroplating as in Claim 3 wherein said cathodic current pulses have a duty cycle in the range from approximately 0.2% to approximately 10%.

7. A method of electroplating as in Claim 2 further comprising alternating cathodic and anodic current pulses superimposed on said dc cathodic current.

8. A method of electroplating as in Claim 7 wherein said current pulses carry currents in the range from approximately 25 milliamperes per square centimeter to approximately 250 milliamperes per square centimeter.

9. A method of electroplating as in Claim 7 wherein said current pulses have pulse lengths in the range from approximately 0.5 milliseconds to approximately 10 milliseconds.

10. A method of electroplating as in Claim 7 wherein said cathodic current pulses have a duty cycle in the range from approximately 10% to approximately 50%.

11. A method of electroplating as in Claim 1 wherein said additive is selected from the group consisting of mercaptopropane sulfonic acid, dimercaptopropane sulfonic acid, N-N dimethyl dithiocarbamic acid-3-sulfopropyl-ester, polyethylene glycol, polypropylene glycol, polyethylene oxide, polypropylene oxide, and copolymers and mixtures thereof.

12. A method of electroplating a metal onto a surface comprising a plurality of recessed features, the method comprising:

a) contacting said surface with an electroplating solution comprising metal ions and an additive for a time sufficient for adsorption of said additive onto said surface;

b) applying a dc cathodic current having an initial value through said surface, the initial value such that electroplating occurs

preferentially on bottoms of recessed features having the least diffusion-accessibility; and

c) increasing said current from said initial value such that electroplating progresses to bottoms of features having higher diffusion-accessibility.

13. The method of Claim 12 wherein said additive comprises at least one chemical species that suppresses electroplating when adsorbed on said surface and wherein said additive is transformed upon passage of the dc current through said surface so as to lose said electroplating suppressing activity.

14. The method of Claim 13 wherein said initial value is such that adsorbed additive transformed by said current is replaced by diffusion of additive to a site of said transformation everywhere except on said bottoms of recessed features having the least diffusion-accessibility.

15. The method of Claim 12 wherein the initial value is between about 0 and about 5 milliamperes per square centimeter and increasing said current in step (c) is increasing said current over a period of between about 3 and about 60 seconds to a maximum dc current of between about 4 and about 45 milliamperes per square centimeter.

16. A method of electroplating as in Claim 12 further comprising immediately following step b):

terminating said cathodic current flow;

applying an anodic current pulse;

terminating said anodic current; and

resuming cathodic current flow.

17. The method of Claim 16 wherein the initial value is between about 3 and about 45 milliamperes per square centimeter and applying a dc current is applying a dc current for a time period between about 1 and about 200 milliseconds.

18. A method of electroplating as in Claim 12 wherein said additive is selected from the group consisting of mercaptopropane sulfonic acid, dimercaptopropane sulfonic acid, N-N dimethyl dithiocarbamic acid-3-sulfopropyl-ester, polyethylene glycol, polypropylene glycol, polyethylene oxide, polypropylene oxide, and copolymers and mixtures thereof.

Sub A2

19. A method of mitigating corrosion of a metal layer on the surface of recessed features caused by contact of said metal layer with an electroplating solution, said method comprising cathodically polarizing said metal layer with respect to said solution.

20. A method as in Claim 19 wherein said cathodic polarization is applied prior to or less than approximately 5 seconds following contact of said metal layer with said electroplating solution.

Sub A3

21. A method of mitigating corrosion as in claim 19 wherein said cathodic polarization of said metal layer is performed by causing a cathodic current to flow between said metal layer and a counter electrode.

22. A method of mitigating corrosion as in Claim 21 wherein said cathodic current is in the range from approximately 0.1 milliamperes per square centimeter to approximately 5 milliamperes per square centimeter.

23. A method of mitigating corrosion as in Claim 20 wherein said cathodic polarization of said metal layer is performed by applying a net cathodic

voltage to said metal layer with respect to a copper reference electrode in the electroplating solution prior to said metal layer contacting said electroplating solution.

24. A method of mitigating corrosion as in Claim 23 wherein said voltage is approximately -10 millivolts with respect to said reference copper electrode in said electroplating solution.

25. A method of electroplating a metal onto a surface comprising a field region and a plurality of recessed features, the method comprising:

a) contacting said substrate with an electroplating solution comprising metal ions and an additive;

b) applying a cathodic current through said surface, the cathodic current being sufficiently small that depletion of metal ions and the additive is absent at both the field region and the recessed features, to create a substantially conformal conductive film on said surface;

c) contacting said surface with said electroplating solution for a time sufficient for adsorption of said additive onto said surface;

d) applying a dc cathodic current having an initial value through said surface, the initial value such that electroplating occurs preferentially on bottoms of recessed features having the least diffusion-accessibility; and

e) increasing said current from said initial value such that electroplating progresses to bottoms of features having higher diffusion-accessibility.

26. The method of Claim 25 further comprising continuing step (e) until the aspect ratios of all of said recessed features are less than approximately 0.5.

27. A method of electroplating a metal onto a surface comprising a field region and a plurality of recessed features, the method comprising:

a) depositing a conducting seed layer on said substrate;

b) cathodically polarizing said seed layer with respect to an electroplating solution comprising metal ions and an additive prior to or less than approximately 5 seconds following contact of said seed layer with said electroplating solution;

c) contacting said substrate with said electroplating solution;

d) applying a cathodic current through said surface, the cathodic current being sufficiently small that depletion of metal ions and the additive is absent at both the field region and the recessed features, to create a substantially conformal conductive film on said surface;

e) contacting said surface with said electroplating solution for a time sufficient for adsorption of said additive onto said surface;

f) applying a dc cathodic current having an initial value through said surface, the initial value such that electroplating occurs preferentially on bottoms of recessed features having the least diffusion-accessibility;

g) increasing said current from said initial value such that electroplating progresses to bottoms of features having higher diffusion-accessibility.

h) continuing step (g) until the aspect ratios of all of said recessed features are less than approximately 0.5; and,

i) conformally plating said surface, filling said recessed features.

28. A method of electroplating as in Claim 27 wherein said conductive film on said surface achieves a thickness of at least approximately 500 Angstroms.

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